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Effect of integrated compute-based laboratory environment on students' physics conceptual learning of sound wave properties

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Abstract

The integration of computerized science laboratory environments such as microcomputer-based laboratory (MBL) and computer simulation is mentioned in community of science educator and practitioner and utilized as being an integrated part of scientific inquiry-based classroom for enhancing teacher's teaching and student's learning process in science called "integrated cognitive tool". An effect of structured-inquiry learning within the hybrid science laboratory environment on student's conceptual understanding and conceptual change on sound wave properties was reported in this paper. Thirty of Grade 11 Thai students participated in this research throughout two weeks. Mixed-method research methodology was conducted to explore both quantitative and qualitative outcome of the students' conceptual understanding at before and after participating in the environment, and to explain qualitatively the phenomena of change of their understanding. The qualitative result revealed that students' physics conceptual understanding of sound wave properties were achieved to be scientifically or more scientifically comparing between before and after, and the quantitative result based on Wilcoxon matched pair signed-ranks test showed that this achievement caused them significantly gaining a better conceptual score at the end of their learning. In addition, the qualitative analysis indicated that the students did change of conceptual understanding on physics of sound wave properties in three characteristics such as differentiation, class extension, and reconceptualization. These findings suggested that the hybrid science laboratory environment could help students to improve and comprehend their understanding of physics concept of sound wave properties through the process of conceptual change.

Keywords: Hybrid computerized laboratory environment, Microcomputer-based laboratory, Computer simulation, Conceptual understanding, Conceptual change;

1. Introduction

Problems and difficulties of conceptual learning in science have been found widely across all ages and levels in science education research (Zacharia, 2007). Students of any age come to science classes with informal ideas, disorganized experience, unstructured conception, and initial understanding that usually were unscientific basis because of misinterpretation for science terminology, unmeaning knowledge construction about the physical world, unreasonable explanations for how and why things function over many years of everyday experience disconnected from the reality of world (Postner et al., 1982). Its unscientific basis often interfere constructive process of conceptual learning in science and affect the ability of student to transform scientific explanations learned in

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classroom into useful knowledge for the process of conceptualization of scientific ideas (Duschl & Gitomer, 1991; Zacharia, 2007). This situation reinforces efforts of science educators and educational researchers to foster student's conceptual change in order to promotion of assimilation or accommodation of scientifically accurate conception (Postner et al., 1982).

It has been widely established in the community of science educator and educational researcher that contemporary science learning environments should foster inquiry-based experiences and investigations that promote change of student's conceptual understanding from unscientific conceptions to be accepted scientific conceptions in a specific domain. These inquiry-based scientific practices should take place in the laboratory, the classroom, or the field where students are given opportunities to interact directly with naturally occurring phenomena or with data originating from such phenomena (Pyatt & Sims, 2011). Research has shown that students could be provided effective learning experience of science through the use of actual inquiry-based experimentation (Hofstein & Lunetta, 2004) and through the use of virtual laboratory environments that support experimentation, such as interactive computer-based simulations (Zacharia & Anderson, 2003). Both the use of actual and virtual environments could be used as cognitive tool in conceptual change learning environments (Hofstein & Lunetta, 2004; Zacharia & Anderson, 2003). In addition, the integrative use of both actual and virtual environments as integrated cognitive tool has been reported that it efficiently enhances mechanical process of conceptual change for student's conceptual learning in science (Jaakkola, Nurmi, & Veemans, 2011; Olympiou & Zacharia, 2012; Zacharia, 2007).

2. Literature review

2.1. The integration of computerized laboratory environment in science education

Recently, a contemporary approach of inquiry-based science laboratory experimentation for student learning is the integration of actual (hands-on) and virtual (simulation) computer-based laboratory experiment. The use of both computerized laboratory environment has been reported that they can results on process of conceptual change and help student to repair and accurate their alternative (unscientific) conceptions and to advance their scientific conceptions (Jaakkola, Nurmi, & Veemans, 2011; Olympiou & Zacharia, 2012; Zacharia, 2007). Actual computerized laboratory environment has been referred to "Physicality" or "Real experimentation" that can promote authenticity and application of scientific process and practice and facilitate concrete-to-abstract conceptualization of real-world phenomena (Pyatt & Sims, 2011). In contrast, virtual computerized laboratory environment has been referred to "Virtuality" or "Simulated experimentation" that can be obvious advantage in term of portability, safety, cost-efficiency, minimization of error, amplification or reduction of temporal and spatial dimensions, and flexible, rapid and dynamic data displays (Zacharia, 2007). Researchers found that the computer-simulated experimentation works with remedial by producing change to the alternative conceptions held by learners (Bell & Trundle, 2008; Zacharia & Anderson, 2003; Zacharia, 2007).

3. Methods

3.1. Research design

In order to explore effect of hybrid computerized laboratory environment on students' conceptual learning of sound wave properties, this present study used mixed-methodology research design. The researchers conducted the pre-experimental design of quantitative research methodology to compare scores of conceptual understanding at the beginning and the end of the study from one targeted participants, as one group pretest-posttest design. In addition to collect qualitative data such as characteristics of conceptual understanding and types of conceptual change, the researchers conducted the phenomenological research design to explain phenomenon of the participants' conceptual change, by using method of content analysis.

3.2. Study participants

Thirty of Grade 11 Thai students participated in this study conducted during the 2nd semester of academic year 2010. The participants comprised 17 males and 13 females and their ages rank from 15-17 years old. All of them were studying in secondary education program emphasizing mathematics and science, and they did have satisfactory basic skills in using computer but they never had any experience with using computer for laboratory experiment.

3.3. Domain of conceptual knowledge

Physics of sound is a fundamental topic embedded in many national basic education curriculums. In Thai basic education curriculum, the properties of sound wave are an emphasized topic for almost all levels. For this present study, the studied conceptual knowledge was the properties of sound wave including: 1) reflection, which could be explained as a bouncing of sound wave when it hit a surface; 2) refraction, which is mostly explained by many as the change in the direction or the bending of sound wave, when it pass from one medium to another; 3) diffraction, which could be explained as a change of direction of sound wave as it pass through an opening or around a barrier in its path; and 4) interference, which is explained as a phenomenon that occurs when two sound waves meet while traveling along the same medium.

3.4. Study materials

3.4.1. Microcomputer-based laboratory (MBL)

Microcomputer-based laboratory (MBL) from Vernier Software & Technology is used as a tool for scientific thinking to enhance the construction of physics conceptual understanding on properties of sound wave at macroscopic (observable) level, as show in Figure 1.

Figure 1. The use of MBL in structured-inquiry learning activity

3.4.2. Computer simulation

Computer simulation from Physics Education Technology (PhET) is used as a cognitive tool for conceptual learning to enhance the construction of physics conceptual understanding on properties of sound wave at microscopic (unobservable) level, as show in Figure 2.

Figure 2. The use of computer simulation in structured-inquiry learning activity

3.4.3. The mental model survey form

The mental model survey form is an evaluation tool to determine students' conceptual understanding within their mental model. Ad hoc drawing and reasoning were used to develop the form for the participants, as show in Figure 3. The form consisted of four items situated on the properties of sound wave.

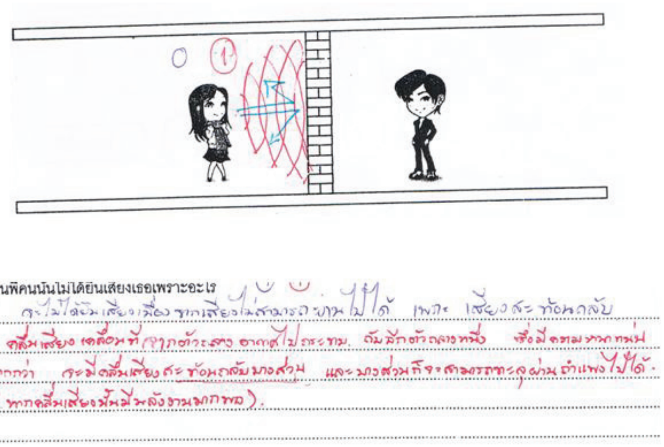

Figure 3. Example of student's ad hoc drawing and reasoning on concept of sound reflection

3.5. Data collection

For investigating students' characteristics of conceptual understanding and its scores, and types of conceptual change, the mental model survey form was administered to the students at the beginning and the end of an inquiry lesson of properties of sound wave as a pretest and a posttest, respectively. The students were attending the inquiry lesson of properties of sound wave throughout two weeks. Finally, all collected data were analyzed within two weeks later.

3.6. Data analysis

For analysis of students' characteristics of conceptual understanding, the content analysis based on scientific ontology of the studied concepts was primarily used for their Ad hoc drawing and reasoning both pretest and posttest. After, a coding and rubric score system for evaluating of conceptual understanding were developed and then the Ad hoc drawing and reasoning were coded and scored quantitatively. The statistical analysis of Wilcoxon matched pairs signed-ranks test was used to compare the difference between pretest and posttest scores. In order to analysis of students' types of conceptual change, the content analysis based on Dykstra, Boyle, & Monarch (1992)'s framework, also, was used to describe analytically their conceptual change.

4. Results

4.1. Students' conceptual understanding in physics of sound wave properties

The comparison of pre-test and post-test conceptual understanding scores based on nonparametric statistics analysis of Wilcoxon matched pairs signed-ranks test discovered that post-test score of students' conceptual understanding in physics of sound wave properties was significantly higher than the pre-test score ($Z=-4.791$, $p<.05$). The statistics of Wilcoxon matched pairs signed-ranks test for students' conceptual understanding are display in Table 1.

Table 1. Statistics of Wilcoxon matched pairs signed-ranks test for students' conceptual understanding scores

		N	Sum of Ranks	Z	Asymp Sig. (2-tails)
CU_Score_Post – CU_Score_Pre	Negative Ranks	30.00[a]	15.50	-4.791	0.000
	Positive Ranks	0.00[b]	0.00		
	Ties	0.00[c]	0.00		
	Total	30.00			

a. CU_Score_Post > CU_Score_Pre
b. CU_Score_Post < CU_Score_Pre
c. CU_Score_Post = CU_Score_Pre

4.2. Students' conceptual change in physics of sound wave properties

In Table 2, it presents results of students' conceptual change in physics of sound wave properties. The change of students' conceptual understandings has been found in three types such as differentiation, class extension, and reconceptualization, around four physics concepts of sound wave properties including reflection, refraction, diffraction, and interference, as show in the Table 2.

Table 2. Summary of students' conceptual change in physics concept of sound wave properties

Physics concept	Type of conceptual change					
	Differentiation		Class extension		Reconceptualization	
	%	Characteristics (Example)	%	Characteristics (Example)	%	Characteristics (Example)
Reflection	13.33	*Pretest*: Sound wave will be reflected after bouncing off a surface. *Posttest*: Sound wave will be reflected after bouncing off a surface but some of its will be absorbed by the surface.	26.67	*Pretest*: Sound wave will be reflected after bouncing off a surface. *Posttest*: Sound wave will be reflected after bouncing off a surface but some of its will be absorbed by the surface. In addition, amount of reflection and absorption for sound wave depend on density of surface or amplitude of sound wave.	60.00	*Pretest*: Particles of sound wave will move passing through a surface and all mediums. *Posttest*: Sound waves make particles of medium vibrating back and forth in the same direction and opposite direction of energy transport. When they hit a surface, their wave will be reflected and absorbed by the surface.
Refraction	-	-	33.33	*Pretest*: Sound wave can travel through mediums which has different density in the way of refraction. *Posttest*: When sound wave travel through different mediums which has different density, diffraction of sound wave will be happened. In addition, its wavelength and speed will be changed when traveling through different density of medium but its frequency will be the same.	33.33	*Pretest*: Sound waves can travel from source of sound through inert gas without any bending of direction. *Posttest*: When sound wave travel through different mediums which has different density, diffraction of sound wave will be happened. In addition, its wavelength and speed will be changed when traveling through different density of medium but its frequency will be the same.
Diffraction	-	-	76.67	*Pretest*: Sound wave can travel bendingly through mediums. *Posttest*: When a sound wave is disturbed by the edge of a barrier, there will produce a new circular wavefront of sound wave.	63.33	*Pretest*: Particles of air diffract randomly all direction. *Posttest*: When a sound wave is disturbed by the edge of a barrier, there will produce a new circular wavefront of sound wave as an original source of sound.
Interference	90.00	*Pretest*: A change in distance between the observer and the two-point sources of sound provides a different effect to the listener. *Posttest*: The observer will hear a change in pitch on each change of distance between the observer and the two-point sources of sound because of the constructive and destructive interference of sound wave.	-	-	23.33	*Pretest*: All observers at different positions will hear sound the same. *Posttest*: The observers will hear a change in pitch on each change of distance between the observers and the two-point sources of sound because of the constructive and destructive interference of sound wave.

5. Discussions

The quantitative result shows that the students' post-test score of students' conceptual understanding in physics of sound wave properties was higher significantly than the pre-test score. Correspondingly, the qualitative results indicate that the characteristics of students' pre-conceptual understanding in physics of sound wave properties have been changed in comparing with their post- conceptual understanding, to be scientific conceptions and more accurate and extended scientific conceptions. The qualitative analysis also reveals that the students' conceptual change in physics of sound wave properties occurred in three types of conceptual change including differentiation, class extension, and reconceptualization. These findings clearly indicate an efficiency of integrated computer-based laboratory environment (actual and virtual experimentation) that the environment can effectively help students to transform and change their scientific and alternative conceptions, respectively, to be accepted scientific conceptions in the community of science. The evidence is consistent with research findings of Jaakkola, Nurmi, and Veemans, (2011), Olympiou and Zacharia (2012), and Zacharia (2007) that the integrative use of both actual and virtual environments has an potential advantage in enhancing process of conceptual change in order to correct student's conceptual learning in science. Therefore, this type of science learning environment could be determined as effectively integrated cognitive tool for students' learning in science concepts.

6. Conclusion

This paper reported an effective use of integration of actual (hands-on) and virtual (simulation) computerized laboratory environments for assisting students' conceptual learning on physics of sound wave properties. This particular type of science learning environment illustrated that it can be effectively integrated cognitive tool to repair and improve students' physics conceptual understanding of sound wave properties. By the way, findings of this present study may offer physics teachers with new understanding into how to help student changing their alternative conceptions by integrative using of computerized laboratory experimentations.

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